Title of the Proposal: Modular Multilevel Converters: from classic DC/AC to emerging DC/DC applications

- Presenter(s):
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- Brief description:

  Modular Multilevel Converters (MMC), with distinctive features of modularity, scalability, easy assembly, high quality voltage waveform, outstanding control performance, easy redundancy and high efficiency, are becoming a competitive power conversion topology for medium and high voltage applications. They have already revolutionized voltage sourced converters (VSC) based high voltage direct current (VSC-HVDC) power transmission systems, pushing the voltage and power ratings to an unprecedented high level, and are the key technology for building multi-terminal HVDC systems and future DC grids. At present, MMCs are also being considered in many medium-voltage (MV) applications, such as machine drives, energy storage interface etc.

  However, the use of hundreds of sub-modules involving thousands of components and associated control and measurement signals, demands very high requirements for the control, monitoring, and communication of the MMC. Simultaneous management of multiple control objectives, including control of active/reactive power, regulation of the input and output voltages/currents, balancing of the sub-module capacitor voltages, suppression of the circulating current, further increases the control difficulties. Over the past years, significant research efforts have been made in the academics and industries to tackle these problems. The purpose of this tutorial is to provide a systematic overview of the MMC on its operating principles, converter models, modulation strategies, control schemes etc., and to give a comprehensive review of the latest achievements, emerging applications, and remaining challenges.

  This tutorial will start with an introduction of MMC characteristics and operating principles. Detailed MMC control strategies will then be described including the available modulation schemes, capacitor voltage balancing methods, circulating current control, as well as the capacitor pre-charging and fault tolerant operation. Efficient modelling and simulation techniques for MMC are also presented. Furthermore, this tutorial will give special emphasis to the applications of MMC: 1) MMC in HVDCs, specifying the system configuration, multi-terminal and DC grid operation, and protection methods under DC faults; 2) MMC used as variable-speed drives, showing its great feasibility and advantages over other multilevel topologies, but also revealing the disadvantage of the excessive capacitor voltage ripple at low speeds and possible methods for its attenuation.

  Recently, VSC-HVDCs in multi-terminal and even the HVDC grids are highly expected in both academia and industry for better integration of large-scale renewable energy sources and strengthening the network.
stability and reliability. Nevertheless, just like the role of transformer in AC systems, DC grids also require such a device to exchange power between networks with different voltage levels. As DC circuit does not satisfy the law of Electromagnetic Induction, it is not possible to use magnetic transformers to convert DC voltage but has to rely on power electronics technology. Although the DC/DC power-electronic converters have been widely studied and applied at low-power applications and a myriad of topologies exist, most of these topologies are not readily scaled up to hundreds of kilovolts and megawatt power ranges due to the limitations of losses, cost, $dv/dt$, and voltage ratings of the semiconductors. To overcome these limitations, several novel HV DC/DC converter topologies based on MMC have been proposed during the last few years. This tutorial will give a systematic review of the latest development in this field. Particularly, the capacitive energy transfer (CET) principle based modular DC/DC converters are discussed, which includes a series of new topologies potential for MVDC/HVDC applications, showing very attractive features of low cost, high efficiency, small footprint, and simplicity. These topologies will be explained with simulation and experimental demonstrations.

- **Duration:**
  Presentation duration: 3 hours in total

- **Outline:**
  - **Circuit Topology and Principles of MMC:** (20mins)
    - Backgrounds
    - MMC Topology Features
    - Operating Principle
    - Circuit Model
  - **Modulation and Capacitor Voltage Balancing:** (25mins)
    - Low Switching-Frequency Modulation Schemes
    - High Switching-Frequency Modulation Schemes
    - Capacitor Voltage Balancing Methods
  - **Control, Modelling, and Simulation:** (30mins)
    - Converter Control
    - Circulating Current Suppression Control
    - Fault Detection and Localization Strategies
    - Average MMC model and simulation
  - **Coffee Break:** (20mins)
  - **Applications of MMC in HVDC:** (20mins)
    - General MMC-HVDC System Configuration
    - Multi-Terminal VSC-HVDC Systems and DC Grid
    - Characteristics of MMC-HVDC systems during DC Faults
    - Fault Protection and Ride-through of MMC under DC Faults
  - **Applications of MMC in Medium-Voltage Drives:** (20mins)
    - Brief Introduction of Available MV Drive Topologies
    - Low-Speed Operation Challenges
    - Capacitor Voltage Ripple Suppression Methods
    - Back-to-Back MMC Motor Drive System
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- **MMC DC/DC Converters**: (20mins)
  - Front-to-Front (FTF) MMC DC/DC Converter
  - MMC DC/DC with Voltage/Current Injection
  - MMC DC Auto Transformer
  - Other MMC Derived DC/DC Converters

- **Capacitive Energy Transfer (CET) Modular DC/DC Converters**: (25mins)
  - The Principle of Capacitive Energy Transfer
  - Monopolar CET Modular DC/DC Converters
  - Bipolar CET Modular DC/DC Converters
  - Future Trends

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-Brief CVs:

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**Bios:** Dr. Fujin Deng received the Ph.D. degree in Energy Technology from the Department of Energy Technology (ET), Aalborg University (AAU), Aalborg, Denmark, in 2012. He joined the Southeast University in 2017 and is currently a Professor in the School of Electrical Engineering, Southeast University, Nanjing, China. From 2013 to 2015 and from 2015 to 2017, he was a Postdoctoral Researcher and an Assistant Professor, respectively, in the ET/AAU, Aalborg, Denmark. Dr. Fujin Deng is a Senior Member of IEEE and currently he is the Head of Department of Power Electronics, School of Electrical Engineering, Southeast University. He has conducted a number of research projects and published more than sixty journal papers. His main research interests include wind power generation, multilevel converters, high-voltage direct-current transmission technology, and offshore wind farm-power systems dynamics.
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Bios: Dr. Binbin Li received his PhD degree in Electrical Engineering from Harbin Institute of Technology (HIT), China, and is currently an Associate Professor in School of Electrical Engineering and Automation, HIT. He has been selected in the Young Elite Scientists Sponsorship Program by China Association for Science and Technology. Dr. Li is associate editor of IEEE Open Journal of the Industrial Electronics Society and member of IEEE and member of Editorial Board for Journal of Power System Protection and Control. He has conducted a number of research projects and published a series of IEEE Transaction papers, which are related with the modular multilevel converters.

- Relevant publications:


